Annals of the Royal College of Surgeons of England (1983) *vol.* 65

ASPECTS OF TREATMENT*

Emergency surgery for stab wounds to the heart

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Key words: HEART; STAB WOUND; ACUTE TAMPONADE; THORACOTOMY; HAEMORRHAGE; CEREBRAL PERFUSION.

Summary

A cardiac stab wound is an uncommon and potentially lethal injury. With appropriate treatment, better than 90% of those admitted alive will survive. This paper outlines the presentation and management of patients with cardiac stab wounds, based on the experience of the Glasgow Royal Infirmary and a review of the literature, illustrated by relevant case histories.

Introduction

In the United Kingdom, cardiac stab wounds are not common. Indeed, the UK Thoracic Surgical Register for 1980 recorded only 18 operations for cardiac injuries of all kinds *(1)*. The heart will be penetrated in about 15% of all stab wounds to the chest *(2)*, but less than 50% of those with cardiac penetration will reach hospital alive *(3)*.

Based on the experiences of the Glasgow Royal Infirmary, and a review of the literature, this paper outlines the presentation of these patients and gives practical advice on their management in situations where there are no experienced cardiothoracic surgeons.

Clinical presentation

Patients with cardiac stab wounds tend to be young and otherwise healthy. The clinical presentation may be broadly one of three types (though injury to other organs, e.g. lung or oesophagus, may complicate the clinical picture):

Group 1:	Chest wound, little or no sign of shock, possible cardiac penetration.
Group 2: [about 30%]	Chest wound, hypotension which often responds to transfusion, probable cardiac penetration, but not in acute haemodynamic difficulty.
Group 3: [about 10%]	The 'apparently dead', chest wound, unconscious, absent pulses, dilated pupils, no recordable blood pressure (Fig. 2).

If the chest wound overlies the cardiac silhouette, there is a better than 60% chance that the heart has been penetrated *(4)*. On the left side, wounds between sternum and nipple may injure the right ventricle. Further lateral to the nipple, the left ventricle is at risk. On the right side, the right atrium and great veins are at risk medial to the nipple, and the left atrium posterior to the mid-axillary line, assuming pentration is approximately vertical to the skin wound. However, irrespective of the chamber penetrated, the presentation depends upon the degree to which blood either accumulates within the pericardium, producing acute tamponade, or passes through the pericardial wound into the chest, or to the exterior, producing signs of hypovolaemia.

Patients with a stab wound of the chest and little sign of shock [Group 1] will tend to have a wound which passes obliquely through the wall of the heart which bleeds relatively little; there is a large wound of the pericardium, producing signs mainly of haemorrhage. Blood will usually accumulate in the pleural space and may be drained. It is this type of cardiac wound which is most likely to seal spontaneously. Patients with a chest wound and hypotension when first seen, usually responding to volume replacement [Group 2], will often have a haemothorax. Rapid transfusion of 500–1000 ml of plasma will usually restore the blood pressure and pulse to normal. However, these patients may well have some degree of tamponade which is masked by hypovolaemia from concomitant haemorrhage. In this group, restoration of haemodynamic stability should not be taken to indicate a small, potentially self-sealing wound, as the sudden development of acute tamponade with little or no cardiac output may be the first evidence of further bleeding from the cardiac wound, this being more likely with the restoration of cardiac filling pressures by transfusion.

The unconscious but warm patient [Group 3] presents the receiving surgeon with by far the greatest challenge. These patients have acute tamponade, usually associated with hypovolaemia. Cardiac electrical activity is often present but, because of the accumulaion of blood and clot within the pericardium, there will be little, if any, cardiac output. External cardiac massage is ineffective. The pupils will be dilated or dilating, and the patient unconscious, though possibly still making occasional spontaneous respiratory efforts. Perhaps surprisingly, these patients have about a 15% chance of leaving hospital alive with appropriate treatment (Personal communication Mattox KL). Occasionally patients are seen who have multiple stab wounds, often to the head, neck and thoracoabdominal regions, as well as the heart. In the UK, such wounds are exceptionally rare—most of these cases never reaching hospital—but, generally speaking, treatment should follow that outlined for Group 3 patients (see below), for unless the acute tamponade is rapidly relieved, no other resuscitative measure can be effective.

Pathophysiology of acute tamponade

When blood or clot accumulate within the intact pericar-

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The Editor would welcome any comments on this paper by readers

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dium, diastolic filling of the ventricles is severely impaired, as the pressure within the pericardium rises. Eventually there may be no cardiac output, though the heart is electrically active and an ECG may be relatively normal. Clinically the central venous pressure rises and the blood pressure falls.

In mild tamponade, where there is still some cardiac output, *pulsus paradoxus* may be found. This is best seen when the arterial pressure is displayed on a monitor after cannulation of a peripheral artery and, essentially, is the diminution of the height of the pressure trace during inspiration. In co-operative patients the femoral pulses can be felt to be reduced or disappear on inspiration. As tamponade worsens and the blood pressure falls so it becomes more difficult to elicit *pulsus paradoxus*.

Where hypovolaemia is present, central venous pressure may be low despite mild tamponade. However, as hypovolaemia is corrected, the venous pressure will show an exaggerated rate of rise to an abnormally high level.

Investigation and treatment

When Group 1 patients are seen, cardiac penetration may not at first be suspected. Venous access should be gained for rapid transfusion, preferably at two sites, and an erect chest X-ray obtained. Haemothorax, pneumothorax, or both, may be present and should be treated by insertion of a large bore (32F) chest drain connected to an underwater seal, and low pressure suction (10 cm water). The drain is usually best placed in the mid-axillary line at the fifth or sixth interspace on the appropriate side. Re-expansion of the lung should be confirmed by further chest X-ray. The size of the cardiac silhouette is usually normal, and in these patients chest X-ray assessment of heart size is of little use.

Drainage via the chest drain should be carefully monitored, usually every 15 minutes, and if the volume of drainage is greater than 0.5 l per hour over two successive hours, or if the accumulated total is greater than 2 l in the first 6 hours, or if the patient requires transfusion greater than the measured loss to maintain the blood pressure (suggesting accumulation), then the chest should be explored, though the majority of such patients will have injuries to the chest wall or lung vessels, rather than the heart.

Patients in Group 2 should be managed in or near an area where an emergency thoracotomy can be undertaken *(4,5)*. Patients in this group require resuscitation by transfusion, but subsequently may suffer catastrophic deterioration with the development of acute tamponade. As well as venous access, a central venous pressure monitoring line should be inserted. Continuous read-out of arterial blood pressure via a radial artery line is of considerable help, especially if deterioration occurs, and may confirm the clinical impression of *pulsus paradoxus*. If *pulsus paradoxus* is present thoracotomy should not be delayed. The risks of transfer to a cardiothoracic unit are high, in view of the possibility of acute tamponade, and should therefore be avoided, though it may be possible to summon a cardiothoracic surgeon to the patient! These patients are very susceptible to major deterioration during induction of anaesthesia, and it is expedient to prepare the skin and drape the patient before the anaesthetic is administered. Arterial and central venous pressure monitoring is of great assistance is recognising such deterioration, whereupon immediate thoracotomy is the treatment of choice.

Group 3 patients require nothing less than immediate left anterolateral thoracotomy and relief of tamponade *(6)*. As soon as possible, volume replacement is given. Respiration is maintained by endotracheal intubation. The immediate aim is to prevent cerebral damage by restoring cerebral blood flow. This is achieved with internal cardiac massage and is further aided if the patient is head down, rapid transfusion given, and the descending thoracic aorta intermittently occluded to divert blood to the head vessels *(7)*.

Operation

Where operation is necessary, the choice of incision will depend upon the urgency, the site of the skin penetration and estimated trajectory and, to a lesser extent, the familiarity of the operator with median sternotomy.

Pericardiocentesis, once used extensively, has been shown to be useful only to allow time for surgery to be undertaken *(10,12)*. It should never be used instead of operation in patients with evidence of tamponade, for the aspirated blood may have come from within a cardiac chamber. Similarly, even with successful aspiration of the pericardium, considerable blood clot may remain within, and the aspirating needle may itself damage the heart further. Successful pericardiocentesis may prevent death while instruments for thoracotomy are awaited; this is probably its only place in the management but, in the opinion of the authors, when a surgeon finds himself considering pericardiocentesis he should consider these exactly the circumstances in which immediate operative relief of tamponade is required.

CASE 1

Following a road traffic accident, a 16-year-old youth was admitted to a local hospital with blunt chest injury. Bilateral pneumohaemothoraces were drained and, although he had no other injury, 9 l of colloid were transfused over 6 hours. He developed right heart failure which was interpreted as tamponade. Attempted aspiration of the pericardium produced 300 ml of blood and he deteriorated further. Upon transfer to Glasgow later that day, the chest was explored urgently by median sternotomy. Pericardial tamponade was relieved and two freely bleeding puncture wounds, one of the right ventricle and the other of the left anterior descending vein, were repaired. Recovery was uneventful. The punctures were presumably caused by attempted pericardial aspiration.

Resuscitated patients who subsequently deteriorate [Group 2] should undergo left anterolateral thoracotomy with operative relief of tamponade. Where the cardiac wound lies behind or to the right of the sternum, extension across the midline may be necessary for repair. Transecting the sternum without a saw is not always easy. The internal mammary arteries should be controlled with artery forceps and divided, while the cardiac wound is controlled digitally. The sternum can usually be divided with heavy scissors, this being made easier if it is first crushed with heavy forceps.

CASE 2

A 21-year-old man was stabbed 1 cm to the left of the sternum in the sixth interspace in February 1982 and admitted to Glasgow Royal Infirmary. His systolic blood pressure was 60 when first seen. After 500 ml of plasma, pulse and blood pressure were normal. Chest X-ray showed a large left haemothorax which drained 600 ml of dark blood. Arterial and central venous pressure monitoring were commenced. Mild *pulsus paradoxus* was revealed, though the central venous pressure was only 5 cm. While preparations were underway to explore the heart by median sternotomy, the patient suddenly deteriorated (40 minutes after admission). Central pressure rose to 30+, blood pressure fell to 30 systolic, and he became unconscious. Attempted pericardiocentesis was ineffective (see above). The chest was therefore rapidly opened by left anterolateral thoracotomy and tamponade relieved. A large wound of the anterior surface of the right ventricle was controlled digitally while the sternum was transected. The blood pressure rose to 80 as the pericardium was opened. The cardiac wound was controlled with buttressed sutures. Recovery was complete.

For patients unconscious and pulseless with acute tamponade [Group 3], immediate left anterolateral thoracotomy through the fourth or fifth interspace is required, as it is rapid (taking less than 30 seconds) and affords excellent visualisation of pericardium and phrenic nerve when the lung is retracted laterally.

In these patients, relief of tamponade and restoration of cerebral perfusion are the primary objectives, and left anterolateral thoracotomy is the incision of choice. The cardiac wound itself is of lesser importance than the restoration of cerebral perfusion, for there are very few stab wounds which cannot be controlled with digital pressure during internal cardiac massage, especially since there is little bleeding if hypovolaemia is profound. With relief of tamponade, the circulation usually improves substantially and attention can then be turned to the cardiac wound itself. If the wound is to the right of the midline and trajectory suggests a right atrial wound, then right anterolateral thoracotomy may be useful, although cardiac massage after release of tamponade is undoubtedly easier from the left.

CASE 3

A 17-year-old youth was seen in the Accident Department of Glasgow Royal Infirmary in the early hours of New Year's Day, 1982, having been stabbed in the seventh left interspace in the mid-axillary line. He was unconscious, pulseless despite external cardiac massage, and had fully dilated, poorly reacting pupils. He was intubated and made occasional respiratory efforts. Immediate left anterolateral thoracotomy was performed, and cardiac tamponade relieved. A 1 cm wound in the left ventricle was easily controlled digitally while the heart was massaged and the descending aorta occluded by manual compression. He regained consciousness almost immediately, and without massage the blood pressure was 80 systolic. The wound was repaired with buttressed sutures and recovery was complete.

Although many patients with stab wounds to the chest will have no cardiac injury *(2)*, in the main it is sensible to regard these patients as group 1 cases. If operation is needed, it is usually for continued bleeding from a chest drain. When the chest is explored, bleeding is then seen to be from within the pericardium, and the cardiac wound can be dealt with in an orderly fashion. Stable Group 2 patients also fall into this category. Here, a 'planned' operation is possible and the chest should be opened on the side of the skin wound. Median sternotomy gives excellent exposure of the right atrium and ventricle, and is of use if these chambers may be wounded, i.e. wounds medial to the nipples. However, it is difficult to divide the sternum rapidly without a saw, and an extended thoracotomy is probably a more appropriate incision for general use in these situations. Whenever the pericardium is opened, care should be taken to avoid the phrenic nerve.

In suturing wounds of the heart, there are several important rules which should be followed, lest more damage be done to the heart. The major coronary arteries must not be narrowed when sutures are tied. Manoeuvres to avoid this are shown in Fig. 1 *(7)*. If possible, sutures carrying teflon pledgets should be used to prevent 'tearing out'. This is particularly important in the muscular ventricles which are injured in approximately 80% of cases *(12)*. Here the sutures should be quite deep (Fig. 1) *(8)*, and if pledgets are not immediately available, mattress sutures tied with care should be employed.

The atrial walls usually hold sutures well, especially where the pressures within are low as a consequence of hypovolaemia. Occasionally, a side-biting clamp may be of use in wounds of the intrapericardial great vessels, or where the right atrium is injured *(9)*. Clamps should never be used on the ventricles. Under extreme circumstances, a balloon tipped catheter may be inflated within the injured chamber and pulled back to reduce bleeding. This is especially useful in the atria or when more than one chamber is injured.

Outcome and complications

When the management criteria outlined above are applied in centres where many of these injuries are seen, results are excellent *(5)*. Patients arriving in hospital with a discernable blood pressure have a better than 90% chance of survival. Group 3 patients have about a 60% chance of resuscitation, but only a 10–15% chance of leaving hospital alive.

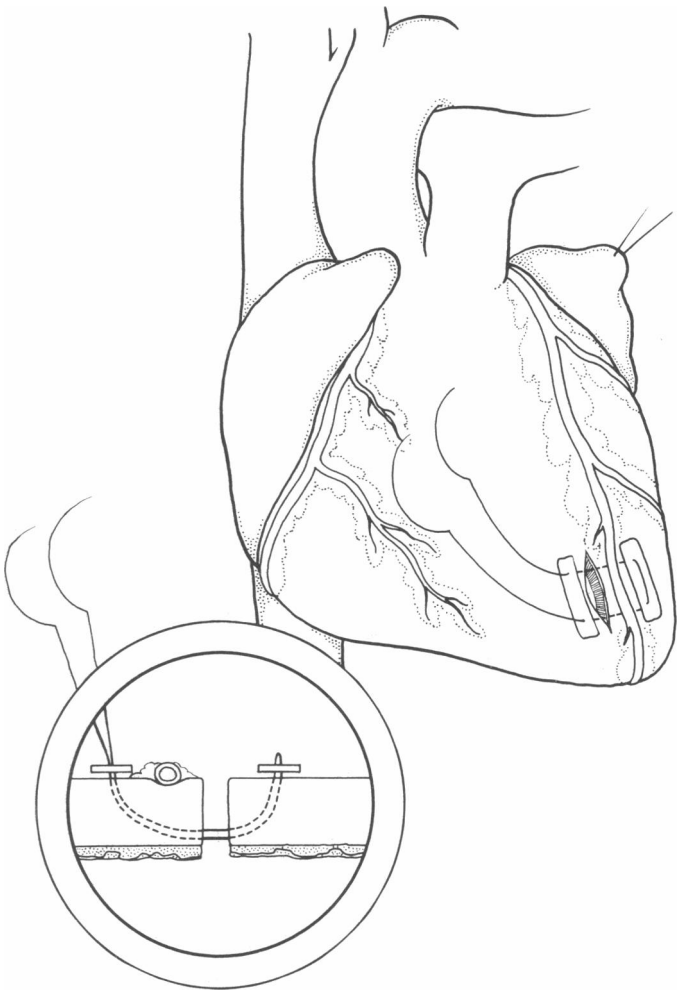

FIG. 1 Technique used to avoid narrowing the large coronary arteries which lie in the epicardial fat.

The mortality of cardiac stab wounds is related to the delay in surgery, cerebral ischaemia prior to surgery in patients with acute tamponade (Groups 2 and 3), and the magnitude of associated injuries of oesophagus, pulmonary hilium, head, neck and abdomen. Multiple stab wounds are rare in the UK, and the major causes of mortality are delayed presentation and delayed surgical intervention. Immediate thoracotomy in Group 3 patients is undoubtedly a worthwhile undertaking *(6)*. The youth of these patients in general enables them to withstand the insult of cerebral hypoperfusion, and such patients should not be denied surgery.

Occasionally the weapon will cause damage to other intracardiac structures *(8)*, producing such lesions as valvular incompetence or ventricular septal defect. Repair of these lesions requires the use of cardiopulmonary bypass, but is only exceptionally necessary if, after haemorrhage is arrested, the patient has gross haemodynamic decompensation. The lesion which is more likely to require cardiopulmonary bypass is damage to a proximal major coronary artery but, fortunately, such lesions are very infrequently encountered. Intracardiac lesions secondary to cardiac penetration can almost invariably be dealt with at a later operation in a cardiac unit.

In general, patients with cardiac stab wounds are initially seen in the Accident Unit by junior surgeons of little experience. If the treatment schedule outlined in Fig. 2 is followed, then patients with potentially retrievable wounds will be given the best possible chance of survival. The major

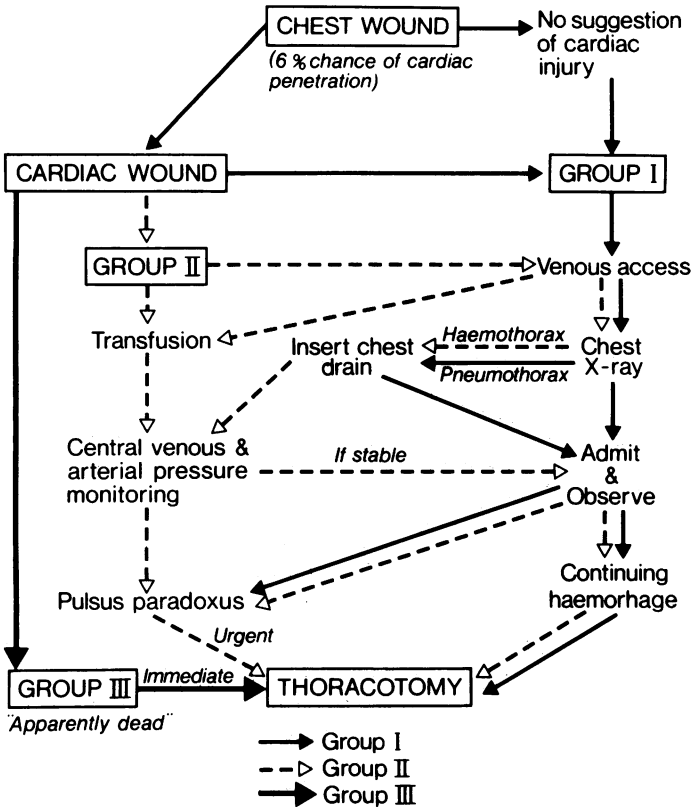

FIG. 2 Management schematic.

elements for success are a high index of suspicion and the willingness to perform emergency exploration when the physical signs warrant it, even though the surgeon may have had no specific training in thoracic or cardiac surgery.

Conclusions

[1] Patients with suspected cardiac penetration should be carefully monitored in an area equipped for emergency thoracotomy. Exploration should never be left to 'the last resort'.

[2] Immediate thoracotomy may save a patient, even if 'apparently dead', and should be applied without hesitation.

[3] Sudden catastrophic deterioration with acute tamponade may occur in apparently stable patients.

[4] In patients with acute tamponade, left anterolateral thoracotomy is the incision of choice.

[5] The clinical suspicion of *pulsus paradoxus*, especially if confirmed on the arterial pressure trace, is an indication for urgent exploration before deterioration occurs.

[6] Where acute tamponade has not occurred, consideration may be given to alternative incisions, e.g. right thoracotomy, median sternotomy.

[7] Sutures should be pledgeted and placed so as to avoid narrowing coronary arteries.

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